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New records of three alien *Solanum* species in Morocco

Hamid Khamar[1], Youssef Dallahi[2], Abdelmonaim Homrani Bakali[3]

1 *Department of Botany and Plant Ecology, Scientific Institute, University Mohammed V in Rabat, P.O. Box 703 Rabat 10106, Morocco*
2 *Laboratoire de Biotechnologie et Physiologie Végétales, Centre de Biotechnologie Végétale et Microbienne Biodiversité et Environnement, Faculté des Sciences, Université Mohammed V de Rabat, Rabat 10000, Morocco*
3 *Regional Center of Agricultural Research of Errachidia, National Institute of Agricultural Research, Av. Ennasr, P.O. Box 415 Rabat Principal, MA-10090 Rabat, Morocco*

Corresponding author: *Hamid Khamar (khamarhamid90@gmail.com)*

Abstract. Recent floristic surveys conducted in various regions of Morocco have revealed three new records of non-native vascular plants of the genus *Solanum*, namely, *S. abutiloides* Bitter & Lillo, *S. bonariense* L., and *S. nitidibaccatum* Bitter. The occurrence of these alien species in Morocco is documented here for the first time. For each species, information on its national habitat and distribution are given. Moreover, the distinguishing morphological features of these three species are compared with the most similar species (including Moroccan *Solanum* species).

Key words. Alien flora, chorology, xenophyte, North Africa

Khamar H, Dallahi Y, Homrani Bakali A (2024) New records of three alien *Solanum* species in Morocco. Check List 20 (2): 544–552. https://doi.org/10.15560/20.2.544

INTRODUCTION

In the region of North Africa, which includes Algeria, Tunisia, Libya, Egypt (excluding the past east of the Gulf of Suez), and the African islands of Macaronesia, Madeira, and the Canary Islands, 34 taxa of the genus *Solanum* have been documented. Among these taxa, only five are considered endemic to the region (Dobignard and Chatelain 2013).

In Morocco, the genus is represented by nine species (Fennane and Ibn Tattou 2005; Fennane et al. 2007). However, in their *Synonymic Index to North African Flora*, Dobignard & Chatelain (2013) noted 13 taxa of the genus in Morocco, including three cultivated species, two naturalized species, and two alien species. These xenophytes were introduced either intentionally (e.g. as crop plants and ornamental garden plants) or unintentionally (e.g. via various means of transport including by sea, air, or overland) (Taleb 2015; Ben Ghabrit et al. 2019; Khamar et al. 2021, 2022).

During some of our regular plant surveys in various regions of Morocco (Sidi Boughaba Park, Oriental High Atlas, and Oum Azza) between 2018 and 2023, we came across three peculiar *Solanum* species. After a critical macroscopic and microscopic examination of the collected specimens, a review of relevant literature (Roe 1967; Chiarini et al. 2007; Vesperinas and Elorza 2012; Särkinen et al. 2018), and discussion on https://www.inaturalist.org/, the specimens were identified as *S. abutiloides* Bitter & Lillo, *S. bonariense* L., and *S. nitidibaccatum* Bitter. These species have never been previously documented from Morocco.

In this article the new records of these three species, together with morphological descriptions, a distribution map, and color photographs for easy identification, are presented.

OPEN ACCESS

Academic editor: Adriano Stinca
Received: 31 January 2024
Accepted: 8 April 2024
Published: 18 April 2024

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METHODS

Field surveys were conducted in the regions of the Oriental High Atlas (near the province of Midelt), Park Boughaba (near Mehdia), and Oum Azza (near Rabat) in Morocco during the spring and summer seasons of 2018 and 2023. Morphological observations, measurements, and analyses of the habits were based on fresh plants material. The distribution map was prepared using data obtained from our field observations. The identities of the collected specimens were confirmed by consulting the pertinent literature and making comparisons with high-resolution photographs of type specimens and their authentic specimens kept at Herbaria G, K, GOET, MO, BR, PH, WIS, BM, and E (herbarium acronyms follow Thiers 2023). The photos were retrieved from the JSTOR database (https://plants.jstor.org). Voucher specimens of all taxa are deposited at the RAB herbarium. The nomenclature follows Roskov et al. (2023), Roskov et al. (2023), and POWO (2023).

All three taxa are listed in alphabetical order. Each entry includes the taxon's accepted scientific name and, if applicable, any pertinent homotypic synonyms, as well as references to detailed morphology, its global distribution, details about its documented occurrence in Morocco, and a distinguishing note to differentiate it from closer species including those found or reported in the country.

RESULTS

***Solanum abutiloides* (Griseb.) Bitt. & Lillo**, in Repert. Spec. Nov. Regni Veg. 12: 136. (Bitter 1913).
≡ *Cyphomandra abutiloides* Griseb.
Figure 1

New records. MOROCCO – **Rabat** • Dafa town, a region in Oum Azza, southeast of Rabat city; 33°56′11″N, 006°47′32″W; 10 m a.s.l.; 04.IV.2018; M. Ibn Tatou leg.; RAB114611 • Oum Azza, near to Akrach bridge, southeast of Rabat; 33°56′11″N, 006°47′32″W, 28.IV.2022; H. Khamar leg.; RAB114612.

Identification. Shrubs or trees 1–3 m high; bark yellowish brown. Young branches terete, yellowish green, soft granular tomentose; indument persistent; hairs mixed, short- and long-stalked, multangulate and dendritic-multangulate, glandular. Leaves strongly scented, thin, ovate, often broadly so, 7–27 cm long, 6–12 cm wide, dark green, velutinous above, hairs spaced to overlapping, mixed sessile and short- stalked, porrect-stellate with especially long central rays, surface stipitate-glandular at 12× magnification, pale green, tomentose beneath, hairs mixed sessile and short-stalked, multangulate, in part glandular, hair surfaces minutely stipitate-glandular; apices acute, bases cordate; petioles 2–10 cm long, soft granular tomentose, hairs sessile, short and partly long, thick-stalked, multangulate and dendritic-multangulate. Axillary leaves usually present, ovate to narrowly ovate. Inflorescences 5–14 cm long; peduncles unbranched for 3.5–8 cm, 1–4 mm thick, lanate, the hairs short to long, thin-stalked, multangulate, dendritic-multangulate, glandular; pedicels 3–6 mm long (to 16 mm in fruit), pubescent, the hairs short to long, thin-stalked, multangulate and dendritic-multangulate, glandular. Flower buds oblong to elliptic, 7–9 mm long at anthesis; corolla lanate, the hairs mixed sessile and short-stalked, multangulate, glandular; calyx lobe sutures not evident, the calyx splitting open early. Calyx relatively thick, lobed 2/3 way to base to nearly parted, the lobes lanceolate to semi-ovate, 2.5–9.3 mm long, 2.2–5.5 mm wide in flower, 8–10 mm by 3.5–6 mm in fruit, pubescent within in upper two-thirds of lobes, hairs transparent, simple glandular and porrect-stellate with long central glandular rays; calyx and hair surfaces minutely stipitate-glandular, and pubescent without,

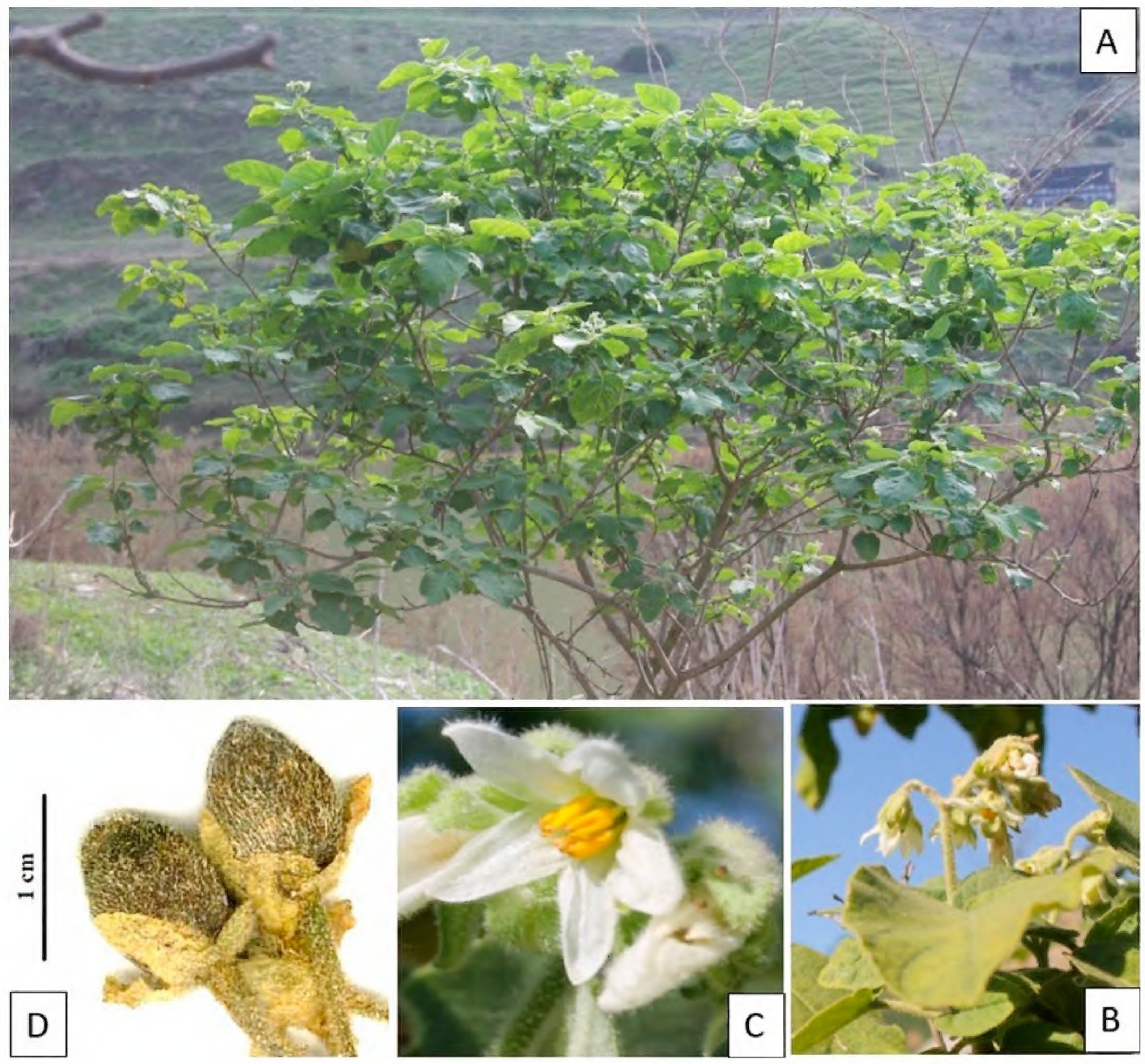

Figure 1. *Solanum abutiloides.* **A.** Habit. **B.** Inflorescence. **C.** Flower. **D.** Fruit (two dry, ripe berries).

hairs sessile, short- and long-stalked, mostly multangulate. Corolla weakly exserted from calyx at anthesis, white to bluish (also reportedly light yellow), 15–18 mm across, the lobes 5–7 mm long, glabrous within or with occasional simple and few-rayed porrect-stellate hairs at tips. Anthers 2.7–4.3 mm long, filaments 1.3–2 mm long. Ovary tomentose, hairs mixed sessile and short-stalked, simple and multangulate with some long ascending rays. Styles exserted from stamens, glabrous or with few porrect-stellate hairs on lower half. Fruits conical to orbicular, 10–11 mm in diameter, yellow when ripe, the tomentum persistent. Seeds 1.2–1.5 mm long, 1–1.3 mm wide, deltoid or suborbicular, yellowish-tan with surface reticulate-punctate (Roe 1972; Morton 1976)

Global distribution. *Solanum abutiloides* is native to central and southern Bolivia and northwestern Argentina (Roe 1972; Morton 1976; POWO 2023) and was introduced in Austria (Verloove and Reyes-Betancort 2011) and Queensland, Australia (Shaw 1995; Bean 2012; Otto and Verloove 2016). In the countries that neighbor Morocco, this species has only been reported from the Canary Islands (Verloove and Reyes-Betancort 2011; Guerra and Reyes-Betancort 2014; Otto and Verloove 2016). Within its general range, this species occurs at elevations of 900–3600 m (only 10 m in Morocco, as reported here), in dry gravelly riverbeds, on steep talus slopes and rocky terrain, in stream-bank scrubland, and in other types of rocky terrain (Morton 1976; Shaw 1995).

Distribution and habitat in Morocco (Figure 4). *Solanum abutiloides* plants were found on limestone soil at an altitude of 10 m in Beld Dafa, Oum Azza landfill in Southeast Rabat, Morocco. At this locality, our botanical surveys revealed only three individuals scattered over an estimated area of 120–130 m^2. So far, this is the only place where this plant has been found in the country.

The pathway of introduction of *S. abutiloides* in Morocco remains unknown. Nevertheless, it is noteworthy that this record is from the Oum Azza landfill, a renowned habitat for diverse migratory bird species (Hilmi et al. 2020). This observation raises the possibility that the presence of this plant in Morocco may be attributed to the dispersal of seeds due to the droppings of fruit-eating birds. The research conducted by Roe (1967) and Tovar et al. (2021) have demonstrated that avian and chiropteran species play a significant role in the process of seed dispersal in *Solanum* (section *Brevantherum*, including *S. abutiloides*). These effective agents facilitate the transportation of fruits and seeds over extensive distances, potentially even across oceans. Therefore, this research aligns with the proposed dispersal scenario.

Taxonomic notes. Based on the data derived from Fennane et al. (2007), it can be inferred that *S. abutiloides* exhibits distinct features that differentiate it from all other known *Solanum* species present in Morocco, regardless of their origin as native or introduced species. Therefore, the identification of this species in Morocco lacks any inherent characteristics that could potentially cause confusion. In fact, according to notes by Roe (1972) and Shaw (1995), *S. abutiloides* can be differentiated from other species (e.g. *S. betaceum* Cav. and *S. mauritianum* Scop.) of the genus by its heart-shaped leaves, calyx deeply divided into lobes, and a pungent scent emitted by its leaves. Additionally, the plant bears hairs with minute glandular structures and stipitate glands on various parts of the plant.

***Solanum bonariense* L.**, Species Plantarum 1: 185 (Linnaeus 1753)
Figure 2

New record. MOROCCO – Kénitra • Mehdia city; 34°14′28.110″N, 006°40′16.52″W; 5–15 m a.s.l.; 25.VII.2023; A. Homrani Bakali and Y. Dallahi leg.; RAB114613, RAB114614, RAB114615.

Identification. Perennial poisonous shrub up to 2 m height, pubescent, with stellate hairs in young plant and glabrous in mature plants. Leaves 2–20 × 3–6 cm, elliptical, ovate or lanceolate, acute, attenuated or pinnate, petiolate up to 3 cm, sinuate-lobate, at least upper leaves entire. Inflorescence in racemiform cymes, isolated or grouped in a paniculiform arrangement, with many flowers (ca. 15), pedunculated; peduncle up to 6 cm, branched. Flowers actinomorphic, hermaphrodite, ebracteate, pedicellate; pedicels up to 20 cm in fruiting, not articulated. Calyx 5–7 mm, campanulate, 5-lobed, crescent, stellate-pubescent; tube shorter than lobes; lobes triangular-lanceolate, acuminate. Corolla 2–3.5 cm in diameter, up to 2.5 times length of calyx, rotaceous, with 5 lobes, blue-violet, stellate-pubescent on the back; lobes broadly ovate. Stamens equal, filaments 0.5–1.5 mm, shorter than anthers, glabrous; anthers 6–7 mm, ovoid or ellipsoid, attenuated towards the apex, conniving, yellow. Style cylindrical, widened at the apex, glabrous or with some glandular hairs at base, exserted; globose stigma. Fruit 0.7–1.1 cm in diameter, including the calyx, spherical, yellow or orange, without sclerosomes. Seeds approximately 1 mm, ± obovoid, irregular, whitish (Chiarini et al. 2007; Vesperinas and Elorza 2012).

Global distribution. *Solanum bonariense* is native and widespread in pastures in Uruguay, northern Argentina, and southern Brazil (Verdes et al. 2006). It has been introduced in Algeria, the Balearic Islands, the Canary Islands, Italy, Spain, Tunisia (POWO 2023), and now Morocco.

Distribution and habitat in Morocco (Figure 4). *Solanum bonariense* is found in sparse patches along the border of the small lake Sidi Boughaba; some individuals are found beneath eucalyptus trees. This plant

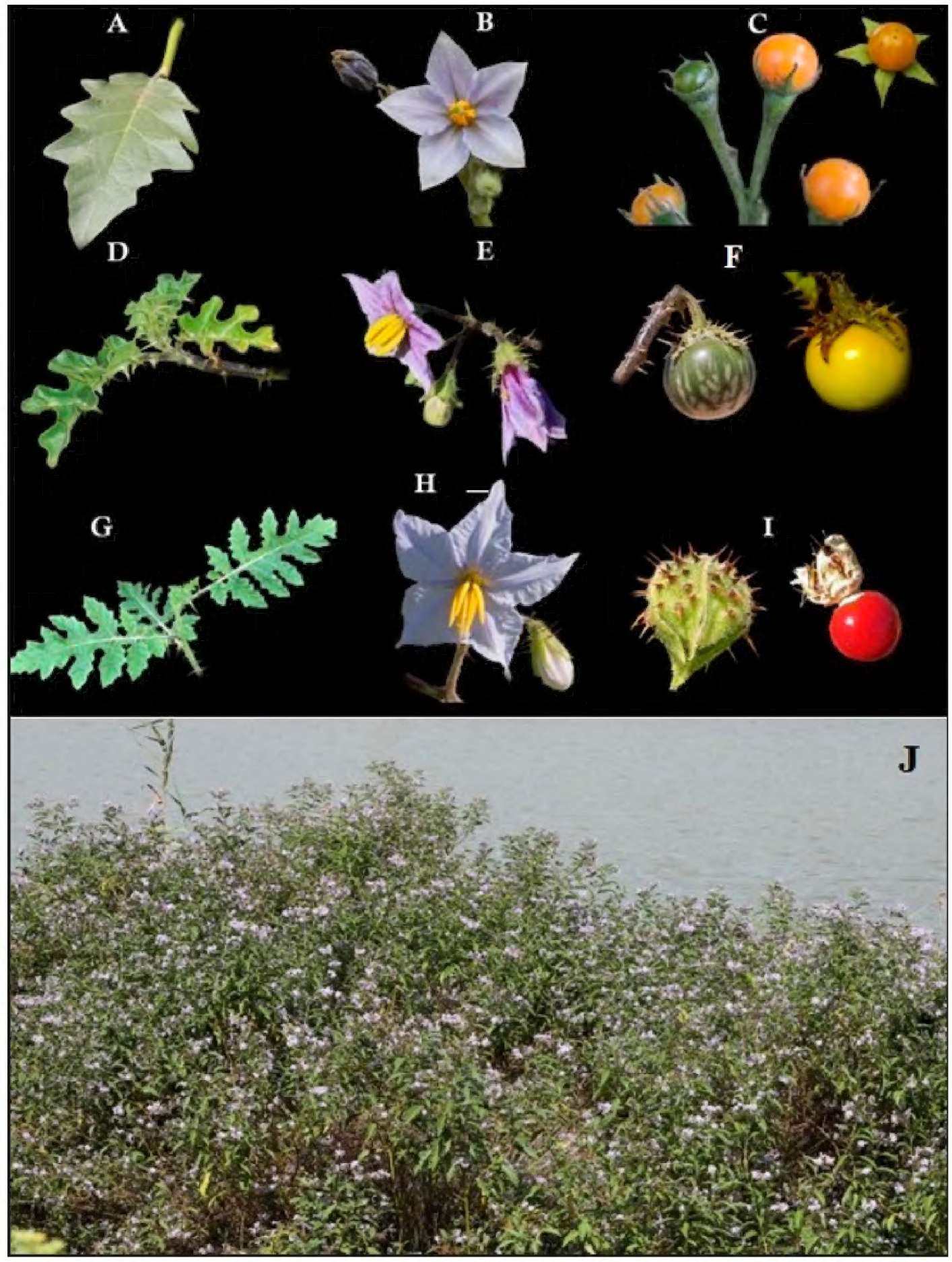

Figure 2. Leaves, flowers, and fruits in *Solanum* species. **A–C, J.** *S. bonariense* **A.** Leaf. **B.** Flower, frontal view. **C.** Fruit. **J.** Habit. **D, E, F.** *S. linnaeanum*. **D.** Leaf. **E.** Flower. **F.** Fruit. **G–I.** *S. sisymbriifolium.* **G.** Leaf. **H.** Flower, frontal view. **I.** Fruit.

was probably cultivated as an ornamental and is currently spreading in the Sidi Boughaba Park. It seems that the plant is also spreading in Marrakech city according to one observation on iNaturalist.org. At the Sidi Boughaba site, a population of approximately 150 flowering individuals were recorded in a strip that extends for about 100 m. This plant lives in generally humid areas and near river courses (Chiarini et al. 2007).

Taxonomic notes. *Solanum bonariense* L. belongs to the section *Torva* Nees of the subgenus *Leptostemonum* (Dunal) Bitter (Nee 1999), informally known as the spiny solanums (Vorontsova et al. 2013). Within the section *Torva*, this species may be confused with *S. lanceolatum* Cav. and *S. guaraniticum* A.St.-Hil. (Chiarini et al. 2007; Cambria et al. 2015). However, the characteristics of *S. bonariense* are shrub-like and rarely exceeding 1.5 m high, stems usually unarmed or with a few small, widely spaced prickles, recurved with a wide and compressed base up to 2 mm long, the indumentum more or less glabrous to the naked eye with few, non-overlapping stellate hairs, and flowers are often white or sometimes purplish-blue. Also, its trichomes have some sessile stellate trichomes with 4–6 lateral rays and a shorter central ray (Chiarini et al. 2007; Vesperinas and Elorza 2012).

***Solanum nitidibaccatum* Bitter**, in Repert. Spec. Nov. Regni Veg. 11: 208. (Bitter 1912).
≡ *Solanum physalifolium* var. *nitidibaccatum* (Bitter) Edmonds, Bot. J. Linn. Soc. 92: 27. (Edmonds 1986).
Figure 3

New record. MOROCCO – **Midelt** • Imilchil region, Takkat n'Islane; 32°14′39″N, 005°31′07.938″W; 2000–2200 m a.s.l.; 05 VII 2023, A. Homrani Bakali leg.; RAB114616, RAB114617.

Identification. Annual prostrate or spreading herbs to 20 cm tall, branching at base. Stems decumbent or ascending, terete, green, not markedly hollow; new growth densely viscid-pubescent with simple, spreading, uniseriate, translucent, glandular trichomes, these 2–8(10)-celled, 1.5–2.0 mm long, with a glandular apical cell; older stems glabrescent. Sympodial units difoliate, the leaves not geminate. Leaves simple, 2.0–5.5(–9.5) cm long, 1.5–5.0(–6.5) cm wide, ovate to broadly ovate, rarely elliptic, membranous, green, concolorous, without smell; adaxial surface sparsely pubescent with spreading 2–4-celled translucent, simple, uniseriate gland-tipped trichomes like those on stem, these denser along veins; abaxial surface more evenly densely pubescent on lamina and veins; major veins 3–6 pairs, not clearly evident abaxially; base attenuate to cuneate, at times asymmetric, decurrent on the petiole; margins entire or sinuate-dentate; apex acute to obtuse; petioles 0.5–2.7(–4.5) cm long, sparsely pubescent with simple uniseriate glandular

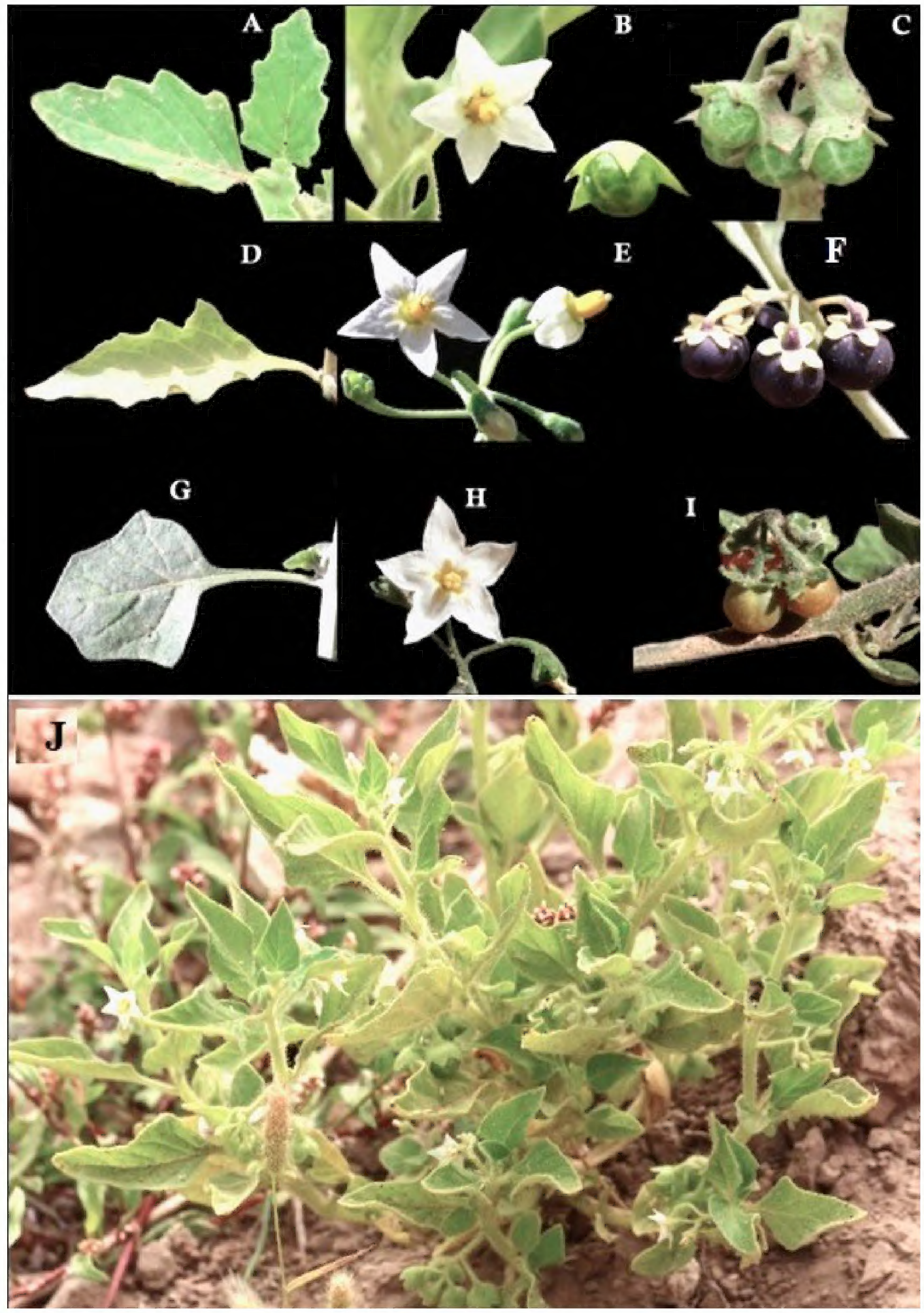

Figure 3. Comparison of cauline leaves, flowers, and fruits of *Solanum* species. **A–C, J.** *S. nitidibaccatum.* **A.** Leaf. **B.** Flower, frontal view. **C.** Fruit. **J.** Habit. **D–F.** *Solanum nigrum.* **D.** Leaf. **E.** Flower. **F.** Fruit. **G–I.** *S. villosum.* **G.** Leaf. **H.** Flower, frontal view. **I.** Fruit.

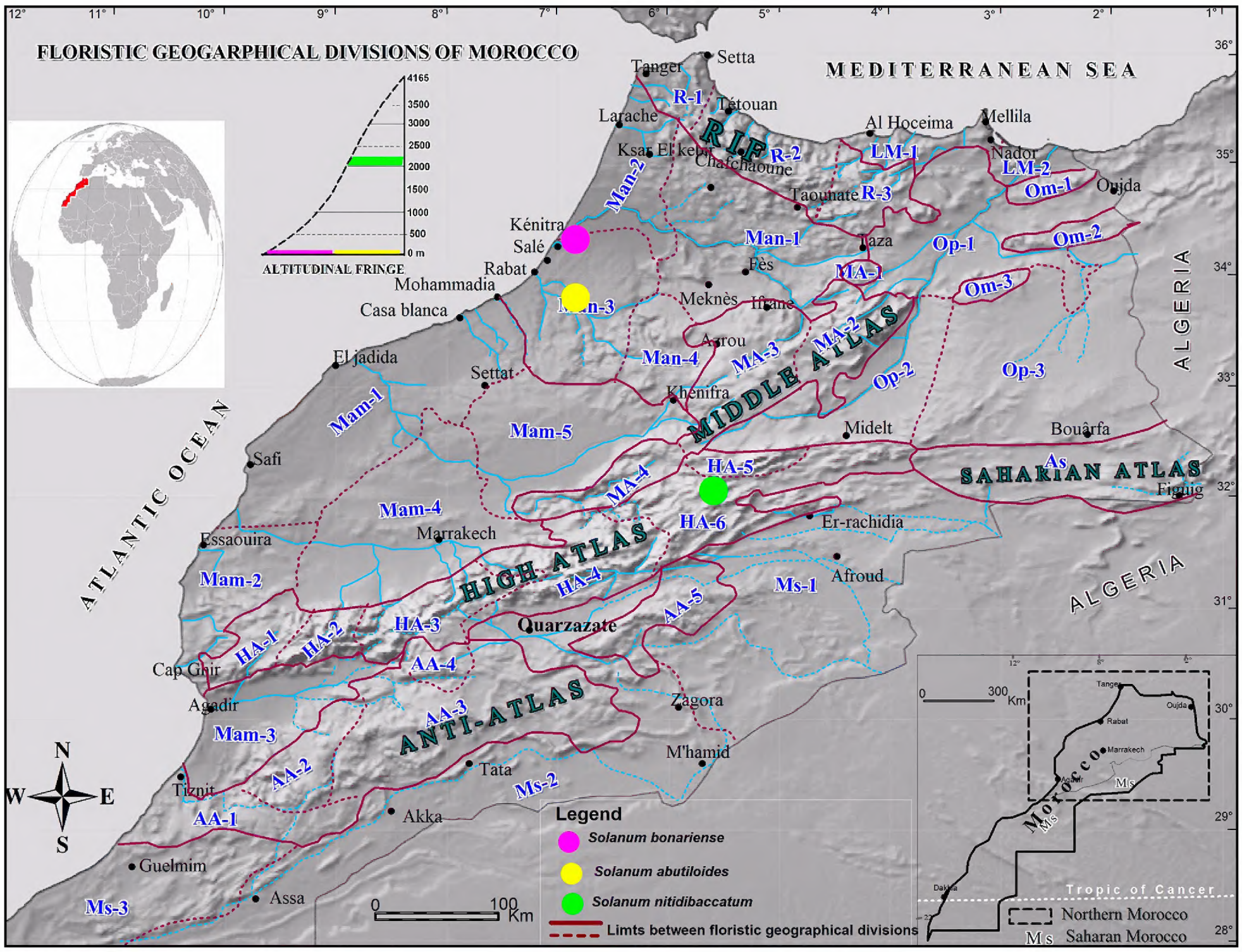

Figure 4. Distribution map of the three new records in Morocco, *Solanum nitidibaccatum* (green circle), *S. bonariense* (purple circle) and *S. abutiloides* (yellow circle).Floristic geographical divisions of Morocco modified from Fennane and Ibn Tattou (1998), where HA = High Atlas Mountains, MA = Middle Atlas Mountains, R = Rif mountains; AA = Anti Atlas Mountains, Mam = Middle Atlantic of Morocco; Man = North Atlantic of Morocco, Ms = Saharan Moroccan, LM, Mediterranean Coast, Op = Eastern-lands, Om = Eastern Mountains and As = Saharian Atlas Mountains.

trichomes like those of the stems and leaves. Inflorescences 1.0–2.0 cm long, generally internodal but occasionally leaf-opposed, simple, the flowers spaced along the rhachis, with 4–8(–10) flowers, sparsely pubescent with spreading trichomes like those on stems and leaves; peduncle 0.6–1.3 cm long, straight; pedicels 4–12 mm long, 0.1–0.2 mm in diameter at base and 0.2–0.4 mm at apex, straight and spreading, articulated at the base; pedicel scars spaced 0.3–1 mm apart. Buds subglobose; corolla only slightly exserted from calyx tube before anthesis. Flowers 5-merous, all perfect. Calyx tube 1–2 mm long, conical, the lobes 1.7–2.5 mm long, less than 1 mm wide, triangular with acute to obtuse apices, sparsely pubescent with 1–4-celled glandular trichomes like those of pedicels. Corolla 4–6 mm in diameter, white with a yellow-green central eye with black V- or U-shaped margins in lobe sinuses, rotate-stellate, lobed ⅓ of the way to base; lobes 2.3–3.2 mm long, 2.5–3.7 mm wide, spreading at anthesis, sparsely papillate-pubescent abaxially with 1–4-celled simple uniseriate trichomes, especially along tips and midvein. Stamens equal; filament tube minute; free portion of filaments 1.5–2.0 mm long, adaxially sparsely pubescent with tangled uniseriate 4–6-celled simple trichomes; anthers 1.0–1.4 mm long, 0.5–0.8 mm wide, ellipsoid, yellow, poricidal at tips, pores lengthening to slits with age and drying. Ovary globose, glabrous; style 2.5–3.0 mm long, densely pubescent with 2–3-celled simple uniseriate trichomes in lower half included in anther cone, exserted 0.2–1.0 mm beyond anther cone; stigma capitate, minutely papillate, green in live plants. Fruit a globose berry, 4–13 mm in diameter, brownish-green and marbled with white (this not easily visible in herbarium specimens) at maturity, surface of pericarp usually shiny; fruiting pedicels 4–13 mm long, ca. 0.2 mm in diameter at base, spaced 1–3 mm apart, reflexed and slightly curving, dropping with mature fruits, not persistent; fruiting calyx accrescent, becoming papery in mature fruit, tube ca. 3 mm long, lobes 2.5–3.5(–4) mm long, 3–4 mm wide, appressed against berry, but berry clearly visible. Seeds 13–24 per berry, 2.0–2.2 mm long, 1.2–1.4 mm wide, flattened, and teardrop-shaped with a subapical hilum, brown, surfaces minutely pitted, testal cells pentagonal. Stone cells usually (1–)2–3 per berry, occasionally absent, ca. 0.5 mm in diameter (Särkinen et al. 2018).

Global distribution. *Solanum nitidibaccatum* is indigenous to southern South America, but it has been sporadically encountered in Europe, North America, Australia, and New Zealand (POWO 2023). Within its natural habitat, it grows in disturbed and cultivated areas in the shade of trees and shrubs; in sandy and rocky places, it can be found from sea level to an elevation of 2000–2700 m; in the Old World, it is most commonly found as a weed in cultivated areas between sea level and 2400 m (Särkinen et al. 2018).

Distribution and habitat in Morocco (Figure 4). *Solanum nitidibaccatum* was discovered in the Oriental High-Atlas region of Morocco, specifically in two locations. The first location is in the Imilchil region, near Lac Isli, where a small group of about 10 individuals was observed growing alongside cultivated crops. The second location is in the Boutaghrar region, near the river of M'goun, where a single population comprised of four individuals was found. So far, the original vector for *S. nitidibaccatum* in Morocco is unknown. However, the presence of this plant on the edge of cultivated fields raises the possibility of its accidental introduction due to seed contamination of an annual crop.

Taxonomic notes. *Solanum nitidibaccatum* has previously been classified as a variety (Edmonds 1986) or subspecies (Fischer et al. 2008) of *S. physalifolium* Rusby. However, recent taxonomic studies by Knapp (2018) and Särkinen et al. (2015, 2018) have established that *S. nitidibaccatum* is indeed a distinct species, closely resembling *S. physalifolium*.

In Morocco, it is possible to confuse *S. nitidibaccatum* with *S. villosum* Mill., *S. nigrum* L., and *S. alatum* Moench (Fennane et al. 2007). Thus, to facilitate the identification and distinction of *S. nitidibaccatum*, we include a dichotomous key.

1 Annual prostrate or spreading herbs to 20 cm tall; leaves ovate to broadly, bases attenuate to cuneate, margins entire or sinuate-dentate; corollas with yellow-green central eyes with black-purple V-shaped margins . . . . . *Solanum nitidibaccatum*
1′ Annual to short-lived, erect to sprawling or weakly scrambling perennial herbs up to 50–100 cm tall 2
2 Plant copiously pubescent; berries black . . . . . *Solanum villosum*
2′ Plant glabrescent, or pubescent with simple hairs; fruit purple-black or dark yellow 3
3 Mature berries dark yellow or orange; stem sharply angled and ridged . . . . . *S. alatum*
3′ Mature berries purple-black or green to yellowish green; stem terete . . . . . *S. nigum*

DISCUSSION

This study reports for the first time three alien species, *Solanum abutiloides*, *S. bonariense*, and *S. nitidibaccatum*, to the list of non-native flora of Morocco. The findings suggest that new alien species are constantly being reported in Morocco due to increased mobility and diversified introduction routes (Homrani-Bakali and Peltier 2020; Khamar et al. 2021, 2022 ; Chambouleyron 2023; Tangi 2023).

Although these species are currently limited to a few sites in Morocco, more data are needed to better understand their distribution in the country across Morocco's phytogeographic regions. It is crucial to ascertain the levels of naturalization of these species, and the ecological and economic consequences they may cause. This article shows the importance of conducting fieldwork to enhance the comprehension of Morrocco's flora. Management strategies for alien plant species are necessary to effectively preserve the native flora.

ACKNOWLEDGEMENTS

We thank Pr. M. Ibn Tattou (Scientific Institute-Rabat) and Pr. Jaime Gil González (Universidad de Las Palmas de Gran Canaria) for their help in identifying the *Solanum abutiloides*, *S. bonariense* and *S. nitidibaccatum* samples. We are also grateful to the anonymous reviewers for their valuable feedback and academic editor for much improvements to the manuscript.

ADDITIONAL INFORMATION

Conflict of interest
The authors declare that no competing interests exist.

Ethical statement
No ethical statement is reported.

Funding
This research received no specific funding.

Author contributions

Conceptualization: HK. Data curation: HK, AHB. Investigation: HK, YD, AHB. Methodology: HK, YD, AHB. Validation: HK, AHB. Visualization: HK, AHB. Writing – original draft: HK. Writing – review and editing: HK, YD, AHB.

Author ORCID iDs

Hamid Khamar https://orcid.org/0000-0001-6008-3264
Abdelmonaim Homrani Bakali https://orcid.org/0000-0003-0719-7267
Youssef Dallahi https://orcid.org/0000-0001-5031-2123

Data availability

All data that support the findings of this study are available in the main text.

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